Analysis of Parasitic Stored Energy Loss and PCB Layout Optimization for 48V-to-1V Series-Capacitor Buck

Data centers consume about 2% of electric energy in major economies. As the thermal design power of microprocessors has seen a steady growth, modern data centers are transitioning from traditional 12-V bus rails to 48-V architectures. The main motivation for raising the bus voltage is to reduce I^2R distribution loss on the input side.

The series-capacitor buck (SCB) is a promising single-stage topology for point-of load (PoL) applications, and there are many complex topologies based on it. However, most prior designs have low switching frequency and large filter inductance, and there are few studies on parasitic elements or design guidelines for the SCB topology.

In this paper, an analytical model for the energy loss related to transistor output capacitance and current commutation loop inductance is provided, including their resonant interactions. For the SCB converter, planar loops outperform their vertical counterparts in terms of loop inductance of PCB traces, additional resistance to high-side switches and noises to inner-layer small signals. A hybrid commutation loop is proposed, which has transistors and inductors on the same side of a PCB and offers opportunities for semiconductor module integration while achieving small loop impedance.

Four- and eight-phase SCB prototypes with minimal loop inductance are experimentally tested, achieving higher efficiency, higher switching frequency and lower filter inductance simultaneously than prior hybrid switched-capacitor solutions. A 48V-to-1.8V MOSFET-based prototype switching at 700 kHz is constructed, which achieves 94.18% peak efficiency, 91.14% full-load efficiency (including gating loss) and 402 W/in3 power density with 30-A current per phase. The same hardware operating at 500 kHz achieves 92.55% peak efficiency and 88.74% full-load efficiency at 1.0-V output voltage. In the end, an example of applying the proposed analytical model for loss breakdown is also provided.

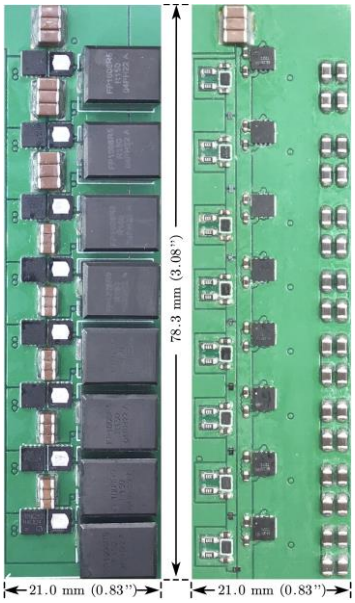

Fig.1. Prototype of 8-phase SCBwith hybrid commutation loops

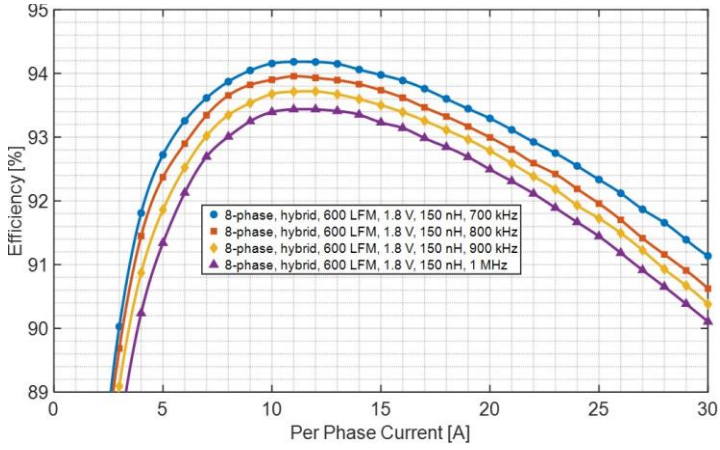

Fig. 2. Efficiency curves of 8-phase series-capacitor buck for 48 V-to-1.8 V conversion